

BASE STATION WITH SLAVE ANTENNA FOR DETERMINING THE POSITION OF A MOBILE SUBSCRIBER IN A CDMA CELLULAR TELEPHONE SYSTEM

FIELD OF THE INVENTION

The present invention relates generally to cellular telephone systems. More specifically, the present invention relates to systems and methods for determining the geographical position of a mobile subscriber within a cellular telephone system. Still more particularly, the present invention relates to a method for locating a mobile subscriber within a code division multiple access (CDMA) cellular telephone system.

BACKGROUND OF THE INVENTION

There are several desirable reasons for having a service that can determine the position of a mobile radio operating within a cellular telephone system. For example, such a positioning service could be used for locating emergency callers (911) or children positioned within a cellular system. Alternatively, such a positioning service could be used for locating vehicles as part of a dispatching or fleet monitoring system. Also, cellular system operators could use such a positioning service in order to customize service parameters based on an accurate knowledge of mobile telephone location. Such customization could include, for example, providing lower cost services for limited mobility customers. A positioning service would also be of use in locating stolen cellular phones and for investigating fraudulent use of cellular services.

Methods for radio position determination make use of techniques for measuring the propagation delay of a radio signal, which is assumed to travel in a straight line from a transmitter to a receiver at the speed of light. A radio delay measurement in combination with an angle measurement provided by a directive antenna is the fundamental principle of radar location. Radar location is frequently augmented by use of a transponder in the mobile vehicle, rather than relying entirely on the signal reflected by the mobile vehicle.

Alternatively, a so-called trilateration system may be used for locating a mobile radio. In a trilateration system, multiple time delay measurements are made using multiple transmitters and/or receivers. The Loran system is an example of a location system which transmits a series of coded pulses from base stations at known and fixed locations to a mobile receiver. The mobile receiver compares the times of arrival of signals from the different transmitters to determine hyperbolic lines of positions. Similarly, the Global Positioning System (GPS) provides transmission from a set of 24 earth orbiting satellites. Mobile receivers can determine their position by using knowledge of the satellites' locations and the time delay differences between signals received from four or more satellites.

From the above examples, it can be seen that radio position location systems can be divided into two types, those which allow a mobile user to determine its own position, such as GPS, and those which allow another party to determine the position of a mobile transponder such as radar systems. The system disclosed in the present application includes elements of both types, but primarily of the second type, where the fixed portion of a radio system wishes to determine the location of a mobile radio unit positioned within the system. Except in the case of passive radar, such systems generally require the mobile radio unit to transmit a radio signal.

U.S. Pat. No. 5,126,748, entitled "Dual Satellite Navigation Method and System," discloses a method of radio location where the mobile terminal both transmits and receives signals, thereby allowing round trip timing measurements defining circular lines of position to be performed using fewer transmitter sites than required for the Loran and GPS systems in which the mobile terminals contain only receiving capability. In other systems, the mobile terminal may contain only a transmitter and the remaining system elements perform direction finding or multiple receptions of the signal from different locations to determine the position. An example of this is the SARSAT system for locating downed aircraft. In this system, the downed aircraft transmits a signal on the international distress frequency 121.5 MHz (and 273 MHz). An earth orbiting satellite relays the signal to an earth terminal. As the satellite passes overhead, the change in Doppler shift can be detected and a line of position can be determined. Multiple overhead passes by the same or similar satellites can determine a set of lines of position, the intersection of which determines the location of the downed aircraft.

It has long been known that direct sequence spread spectrum signals have useful properties for ranging and position location. Some of the earliest spread spectrum anti-jamming military communications systems also included an accurate ranging capability. GPS is, of course, based on the use of direct sequence spread spectrum waveforms. In GPS, a user's receiver determines its position in four dimensional space-time by making time difference measurements on the signals being received from four or more satellites in view. The satellites are positioned in inclined, 12 hour orbits and arranged so that most of the time in most places, enough satellites will be in view with adequate geometry to permit accurate position calculations. The GPS system informs navigation terminals of current satellite ephemeris information which is required for position calculations.

The Telecommunications Industry Association (TIA) in association with the Electronic Industry Association (EIA) has developed and published an Interim Standard entitled "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System," and referred to as TIA/EIA/IS-95-A, May, 1995 (hereafter "the IS-95 standard.") The IS-95 standard supports a code division multiple access (CDMA) cellular system which synchronizes the transmissions of all cells in a cellular system using the GPS satellite downlink signals to update rubidium clocks. Thus, in the IS-95 CDMA system, timing is transferred from the GPS system directly to the cellular system.

The IS-95 CDMA system can determine the location of a mobile station in three dimensional space-time (time plus two dimensional positioning) provided that the mobile receiver is able to receive and track the pilot signals of three neighboring base stations and is provided with accurate location information of the base stations. Likewise, if three IS-95 base stations are able to make timing measurements of a mobile's signal, the system can determine the location of the mobile station. The IS-95 CDMA system implements the universal frequency reuse principal, wherein all sectors and all cells in the system normally operate on the same frequency. This universal frequency reuse principal is central to CDMA's achievement of high system capacity. However, the implementation of the universal frequency reuse principal in a CDMA system can make locating a mobile station problematic in those instances where a mobile station comes close to a base station. In such instances, it may become